

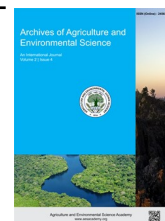


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ORIGINAL RESEARCH ARTICLE



Weight-length, length-length relationships and form factor of three flatfish species from the Bay of Bengal, Bangladesh

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ABSTRACT

Biometrics such as weight-length relationships (WLRs), length-length relationships (LLRs), as well as form factor ($a_{3,0}$) were investigated for three flatfish species, *Cynoglossus lingua*, *Cynoglossus arel*, and *Brachirus pan* which were captured using seines and gill nets between September 2021 and March 2022 from the Bay of Bengal, Bangladesh. The lengths were measured to adjacent 0.1 cm accuracy with a digital caliper and weights to the accuracy of 0.01 g with a digital balance for each individual. The WLRs were accurately adjusted for all species ($r^2 > 0.9500$). *Brachirus pan* had the lowest b value of 2.9543, whereas *C. arel* had the highest b value of 3.2924 amongst the three species. For the investigated species of fish, LLRs were also highly significant ($r^2 > 0.9600$, $p < 0.01$). The estimated form factor values were 0.0023 for *B. pan*, 0.0026 for *C. arel*, 0.0027 for *C. lingua*. New maximum total lengths for *C. arel* and *B. pan* have also been recorded. Since there are no weight-length relationships (WLRs), length-length relationships (LLRs), as well as form factor ($a_{3,0}$) data for these species in Bangladesh; the information supplied here expands the depth of knowledge for these species.

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INTRODUCTION

The Bay of Bengal (BoB) is Bangladesh's principal source of marine fish which spans the far northern section of the Indian Ocean (Rangin and Sibuet, 2017; Habib and Islam, 2020). Approximately 740 marine fish species can be found in the Bay of Bengal's waters (Habib and Islam, 2020, Ullah and Mredul, 2022). Bangladesh produced 46,21,228 metric tons of fish with 6,81,239 metric tons from marine water accounting for 14.74% of total fish production (DoF, 2022). Flatfishes are members of the Pleuronectiformes order of the Osteichthyes class, which encompasses all bony fishes. Pleuronectiformes is a group of flatfish that includes sixteen families, over 100 genera, and 500 species (Nelson, 1994). Though most of the flatfish species dwell in seawater, a few species travel up coastal rivers or

reach brackish or only mildly salty environments. Although certain species have considerable economic worth, the Cynoglossidae (tonguefishes) and Soleidae (soles) families are important groups with minimal economic interest. Long tongue sole, *Cynoglossus lingua* (Hamilton, 1822), Largescale tongue sole, *Cynoglossus arel* (Bloch and Schneider, 1801) from the family Cynoglossidae and Pan sole, *Brachirus pan* (Hamilton, 1822) from the family Soleidae are three widely dispersed flatfish species in Bangladesh (Rahman, 1989) which are distributed well in the Indo-West Pacific region (Munroe, 2001). Flatfish are eaten by people all across the world, and each location has its own essential food species. Aside from its usage as food, and in certain cases as delicacies, flatfishes are an important element of the sportfishing business.

In fisheries and environmental experiments, weight-length relationships (WLRs), length-length relationships (LLRs), as well as form factor ($a_{3,0}$) are very powerful tools for estimating numerous attributes of fish species biology, such as biomass, stock biomass reproduction, growth patterns, and fish species sustainability (Froese, 2006; Rahman et al., 2020). It's important to remember that WLRs, LLRs, and $a_{3,0}$ fluctuate across fish species, based on hereditary body shape as well as physiological aspects including maturation and reproduction (Baeck et al., 2012; Rahman et al., 2021). Seasons or even days can modify this connection (Saha et al., 2019; Rahman et al., 2021). Additionally, the $a_{3,0}$ is extensively applied to compare the body forms of fish from different geographical areas (Froese, 2006). Although quantitative biometric investigations have been undertaken in the Bay of Bengal, there appears to be no reliable study of the weight-length relationships (WLRs), length-length relationships (LLRs), as well as form factor ($a_{3,0}$) of these flatfishes in Bangladesh. As a result, the study intended to first determine WLRs, LLRs, and $a_{3,0}$ for three flatfish species (*Cynoglossus lingua*, *Cynoglossus arel*, and *Brachirus pan*), allowing for straightforward field data transformation using reported size from Bangladesh's Bay of Bengal.

MATERIALS AND METHODS

Fish specimens (*Cynoglossus lingua*, *Cynoglossus arel*, and

Brachirus pan) were caught from the Bangladeshi coast of the Bay of Bengal (Figure 1) between September 2021 and March 2022. Fish samples were collected by seines (mesh size 3-4 cm) and gill net (mesh size 2-4 cm). Samples were gathered and kept in a 10% formalin solution, then confirmed to species level (Talwar and Jhingran, 1991; Lapierre, 2007). FishBase (Froese and Pauly, 2021) was used to double-check scientific names. The research was carried out in accordance with the Bangladesh Fisheries Research Institute's ethical norms. At the laboratory, total length (TL), as well as standard length (SL) to the adjacent 0.1 cm with a digital caliper and total weight (W) to the accuracy of 0.01 g with a digital balance were recorded for a single individual. The weight-length function $W = aL^b$ was equipped for every species, where L was the length (cm) and W was the total weight (g). After logarithmic adjustment, the WLRs were estimated employing linear regression, $\ln(W) = \ln(a) + b \ln(L)$, to compute 'a' representing the intercept and 'b' slope of the relationship (Froese, 2006). A comparable linear regression was also applied to estimate the interactions between TL versus SL. Froese's (2006) formula was applied to determine the form factor ($a_{3,0}$): $a_{3,0} = 10^{\log a - 5(b-3)}$ where S is the average regression of log a vs b = -1.358. Anomalies at the extremities from the estimation were removed before analysis (Froese, 2006). All statistical data and regression analysis to estimate the relations between variables were conducted using Microsoft Office Excel (version 2019) program at a 5% level of significance ($p < 0.05$).

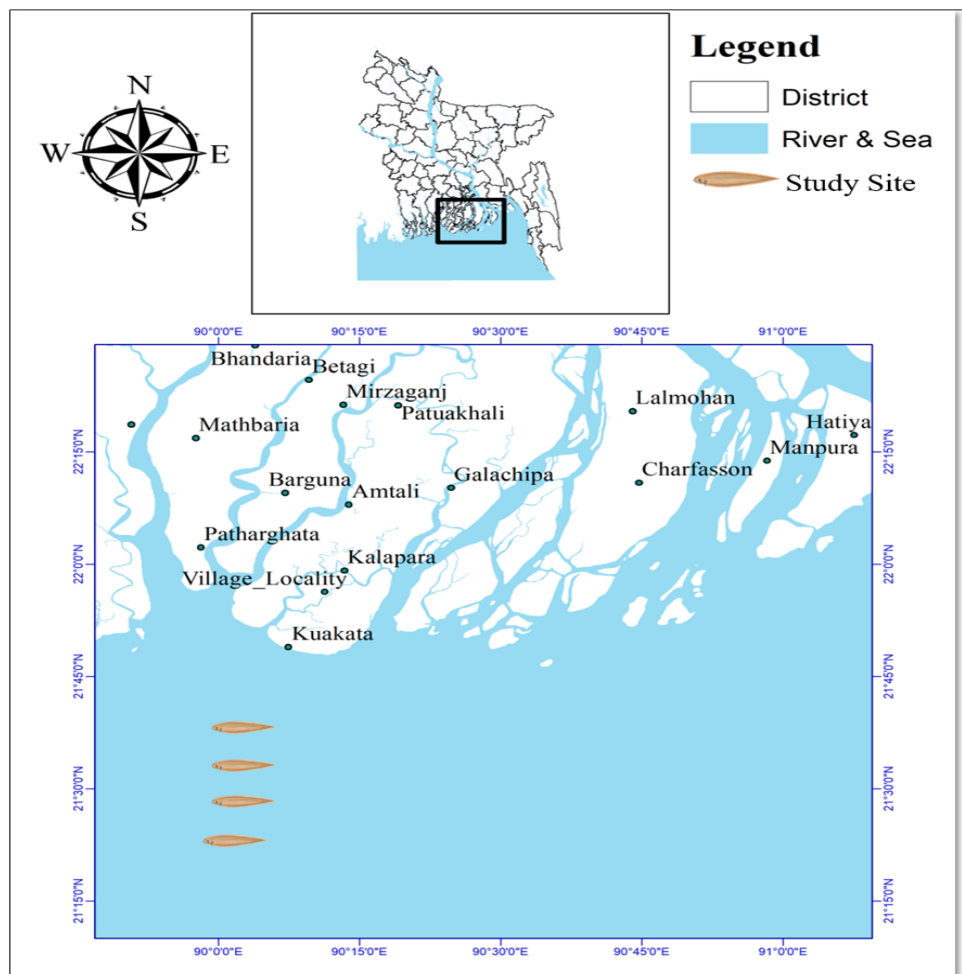


Figure 1. The map depicting the samples obtaining area in the Bay of Bengal, Bangladesh.

RESULTS AND DISCUSSION

A sum of 1130 individuals of three species (*Cynoglossus lingua*, *Cynoglossus arel*, and *Brachirus pan*) from two families was studied in this research. Table 1 shows the total specimen's quantity, total length (cm) highest and lowest, weight (g) highest and lowest, the WLRs properties (a, 95% CL of a, b, and 95% CL of b), as well as the correlation coefficients (r^2). All regression coefficients were significant statistically ($p < 0.01$). Size of the sample, gender, nutrition, weather, gonadal development, the fullness of the stomach, distance covered, sampling time, and even the technology utilized can all alter WLRs (Froese, 2006). All of the species studied in this research agree with Froese's (2006) predicted values for the coefficient of allometry b (2.5-3.5). Karna et al. (2017) found the coefficient of allometry value ($b = 2.88$) for *Cynoglossus lingua* from Chilika lagoon, India; Samanta et al. (2020) found the b value ($b = 2.869$) for *Cynoglossus arel* from Mumbai coast of India; and Ray et al. (2019) found b value 3.049 for *Brachirus pan* from the river of Ganga, India which was more or less similar to the current study. These variances could be due to variations in environmental conditions, species biology, or a combination of the two (Hossain et al., 2012). The association between body weight and length is extremely significant whenever the determination coefficient (r^2) value is more than 0.9500. The determination coefficient value suggested that the values are highly correlated and change accordingly with time. Hossain et al. (2013) also reported that the mesh size of selective fishing gear and preservation protocols during sample

collection may be impacted on the b value.

Length-length relationships (LLRs) are useful in fisheries management since it allows for comparable development investigations (Moutopoulos and Stergiou, 2002; Saha et al., 2019). LLRs had b values ranging from 0.9637 for *Cynoglossus arel* to 1.1620 for *Brachirus pan* (Table 2). The length-length relationships' coefficients of determination (r^2) were all higher than 0.9650. WLRs and LLRs parameters for these three species are provided for the very first time from Bangladesh, as well as for two species updated highest total lengths are also reported, compared to the information in FishBase (Froese and Pauly, 2021). To anticipate growth characteristics, maximum length data is necessary for sustainable fishery resource management (Kaka et al., 2019; Mredul et al., 2021). The highest lengths for two flatfish species found in the Bay of Bengal during this investigation were larger than the peak values documented in Fishbase (Froese and Pauly, 2021). Previously, the maximum length reported for *Brachirus pan* was 11.1 cm in India (Ray et al., 2019) and 40 cm for *Cynoglossus arel* in Iran (Nasri and Taati, 2010). The disparity between the highest length listed in FishBase and the length found in this study could be due to environments and production efficiency (Jiménez, 2008). The estimated $a_{3.0}$ values were 0.0023 for *Brachirus pan*, 0.0026 for *Cynoglossus arel*, 0.0027 for *Cynoglossus lingua* (Table 1). Form factor ($a_{3.0}$) values of these species' were within Froese's (2006) quoted limitations. For these three species, no references are addressing the $a_{3.0}$ in the literature, hence the current findings, therefore, provide the essential foundation for future investigations.

Table 1. The regression parameters of weight-length relationships and form factor of three flatfish species from the Bay of Bengal, Bangladesh.

Species	n	Total length (cm)		Weight (g)		a	95% CI of a	b	95% CI of b	r^2	Length type	$a_{3.0}$
		Min	Max	Min	Max							
<i>Cynoglossus lingua</i> (Hamilton, 1822)	465	19.3	44.2	27.83	196.47	0.0189	0.0171-0.0208	3.0512	2.9603-3.1402	0.9526	TL	0.0027
		17.6	40.7	-	-	0.0029	0.0026-0.0032	2.9885	2.9164-3.0582	0.9765	SL	
<i>Cynoglossus arel</i> (Bloch & Schneider, 1801)	345	15.7	43.6	26.92	207.38	0.0226	0.0155-0.0306	3.2924	3.2537-3.3472	0.9840	TL	0.0026
		13.8	40.3	-	-	0.0031	0.0020-0.0039	3.0718	2.9384-2.9676	0.9883	SL	
<i>Brachirus pan</i> (Hamilton, 1822)	320	8.1	29.4	19.68	116.57	0.0105	0.0079-0.0128	3.2216	3.1553-3.2680	0.9904	TL	0.0023
		7.5	27.6	-	-	0.0019	0.0007-0.0029	2.9543	3.0640-3.0937	0.9856	SL	

Note: n, Sample size; Min, Minimum; Max, Maximum; a, Intercept; b, Slope; CL, Confidence level; r^2 , Correlation coefficient; TL, Total length; SL, Standard length; $a_{3.0}$, Form factor; In bold, new maximum length reported not found to date in FishBase.

Table 2. Length-length relationships parameters for three flatfish species from the Bay of Bengal, Bangladesh.

Species	Equation	a	95% CI of a	b	95% CI of b	r^2
<i>Cynoglossus lingua</i> (Hamilton, 1822)	TL = a + bSL	0.3561	0.3372-0.3685	1.1358	1.1073-1.1528	0.9693
<i>Cynoglossus arel</i> (Bloch & Schneider, 1801)	TL = a + bSL	0.1257	0.1137-0.1369	0.9637	0.9367-1.0152	0.9801
<i>Brachirus pan</i> (Hamilton, 1822)	TL = a + bSL	0.2775	0.2618-0.2861	1.1620	1.1195-1.2052	0.9935

Note: TL, Total length; SL, Standard length; a, Intercept; b, Slope; r^2 , Correlation coefficient.

Conclusion

This research offers weight-length relationships, length-length relationships, as well as form factor for three flatfish species, as well as new highest length records for two species. These findings for three species could be used in stock assessments and management initiatives for these species and further research on reproductive biology is needed.

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Conflict of interest

The authors declare no conflict of interest.

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